Animal Fats and Oils as Industrial Raw Materials

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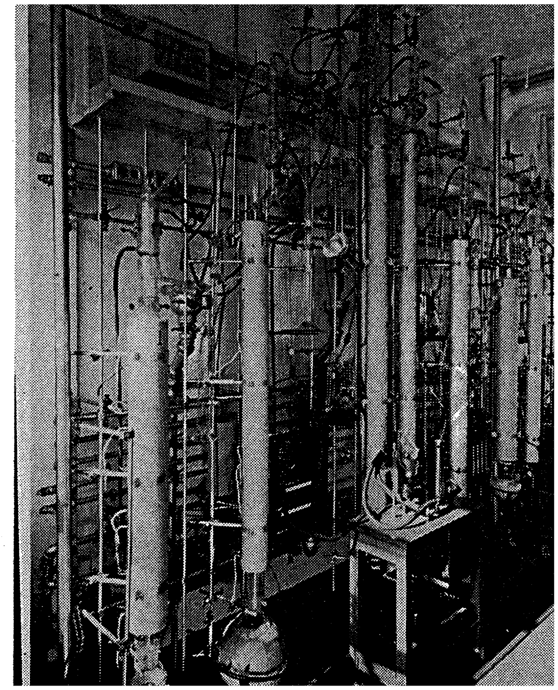


PURIFYING EQUIPMENT. Fractional distillation purifies fatty acids and fatty acid derivatives.

Fats and oils are important constituents of natural products, whether the emphasis be on volume or on economic value. In fact, fats are one of nature's fundamental building blocks and occur in all animals and plants. Primitive man undoubtedly used fats chiefly as food, in most cases not separating them from the other plant or animal tissues with which they were associated. When and how man first became familiar with non-food uses for fats is lost in antiquity, but it seems well established that primitive peoples used them in cosmetics, in religious ceremonies, as illuminants, as lubricants, as medicinals, and possibly to some extent as waterproofing agents. With the advance of civilization, increasing needs and uses for fats and oils were found until today inedible fats are the raw materials for industries of substantial proportions.

The principal inedible fats, other than those used in the drying oil industry, are vegetable oil "foots" obtained as a by-product from the caustic refining of such edible fats as cottonseed and soybean oil, and those animal fats obtained as an important by-product of meat production, inedible chiefly for esthetic reasons. Of these two raw materials, the inedible animal fats are by far the most important volume-wise, the present annual production being more than 2 billion pounds. All fats consist almost exclusively of a chemical combination of a mixture of fatty acids and glycerol. Upon hydrolysis, animal fats yield approximately 90 per cent fatty acids and 10 per cent glycerol. The fatty acids largely determine the uses to which these fats may be put. In recent years about 80 to 85 per cent of the inedible animal fat has been consumed in the manufacture of soap, with glycerol as a by-product. Most of the rest has gone into the production of fatty acids and glycerol (10 per cent), and lubricants and lubricating greases (5 per cent). The small remainder has been used in many miscellaneous applications. The wide variety of these applications is illustrated by the list of industrial uses for inedible animal fats given in Table I, and this list is admittedly incomplete. *(See page 6.)*

In spite of the multiplicity of uses for inedible animal fats, it is becoming apparent that except during periods of abnormally high industrial activity new uses are urgently needed to keep the industry healthy. Important reasons for this are: (1) production of by-product animal fat is increasing as a direct result of increased consumption of meat by the American people, (2) edible animal fats, particularly lard, have decreased in popular acceptance to such a degree that at times, considerable amounts are diverted to inedible channels, and (3) materials which traditionally have been obtained from fats are meeting increasing competition in use from products having non-fat sources, with the result that in several of their important outlets utilization of fat products is remaining static or even decreasing rather than increasing.

This increasing competition calls for increased research to develop new and expanded industrial uses for the inedible animal fats. Research to date has not been conducted on the same scale as similar research on such competitive materials as petroleum and coal tar and therefore has not been able to keep pace with them. In order to promote the healthy growth desired, it is to be hoped that the inedible animal fat industry may enter an era of expansion and development comparable to periods already passed by these industries. To a chemist these periods are all characterized by enormous increases in the isolation and production of chemically homogeneous substances. This approach calls for extensive research, both fundamental and applied, to facilitate the development and manufacture of many new products because relatively few new uses seem likely to be found for the unmodified fats themselves.

Perhaps the greatest increase in industrial consumption of animal fats will be brought about by improving present products to meet expanding and diverse needs. Such an improvement has resulted already from cooperative research carried out under the supervision of The Rubber Reserve Company. This research has led to the development of a special soap essentially free of polyunsaturated fatty acid components and, therefore, superior for use as an emulsifier in synthetic rubber manufacture. There seems to be little doubt that this development has served to retain a substantial proportion of this market of 50 million pounds per year for tallow, while at the same time it has resulted in improved products and important economies for the rubber industry.

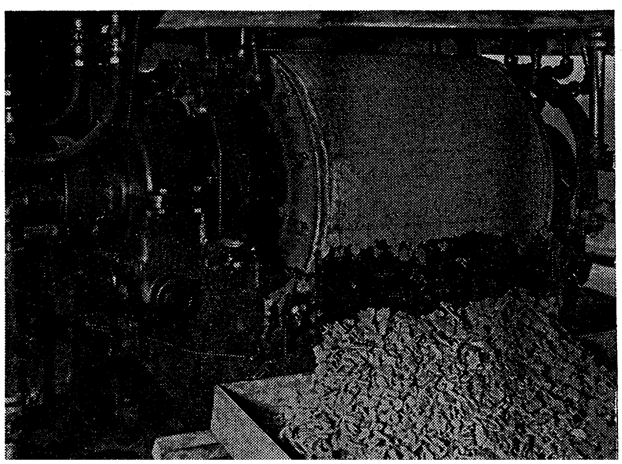
It is probable that investigations of the detailed requirements in other fields of soap application could prevent their replacement by synthetics to some extent. At the same time, it seems reasonably sure that certain fundamental characteristics of soap, such as the familiar curd formation which results from use in hard waters, cause it to be in a vulnerable position for many ordinary uses. It is reliably estimated that detergents are at present replacing an amount of soap which would require about 350,000,000 pounds of animal fats in its manufacture. This loss of market for animal fat, might be minimized also by the development of a satisfactory detergent derived from them. Detergents having many desirable characteristics can be prepared from animal fats and some progress has been made in the commercial production of several. As yet it is too early to state whether all the problems, including those of cost, can be overcome, but certainly the research effort should be more nearly commensurate with the potential rewards.

By analogy with petroleum and coal tar, it seems probable that considerable increase in industrial consumption of animal fats may also come by way of purified fatty acids and their derivatives. Availability of these compounds in a purer form will permit processors to use them in the preparation of specific products for specific purposes. In the past, too little attention has been given to the chemical purity of the fatty acids marketed for industrial use, but happily there is considerable evidence of progress along these lines. For the past decade or so, solid saturated fatty acids and derivatives of high purity (90 per cent) have been available for research and industrial use at moderate prices. This has undoubtedly stimulated new uses, but we are now beginning to see that the production of the liquid, unsaturated component acids of fats in an industrially pure form may be even more fruitful.

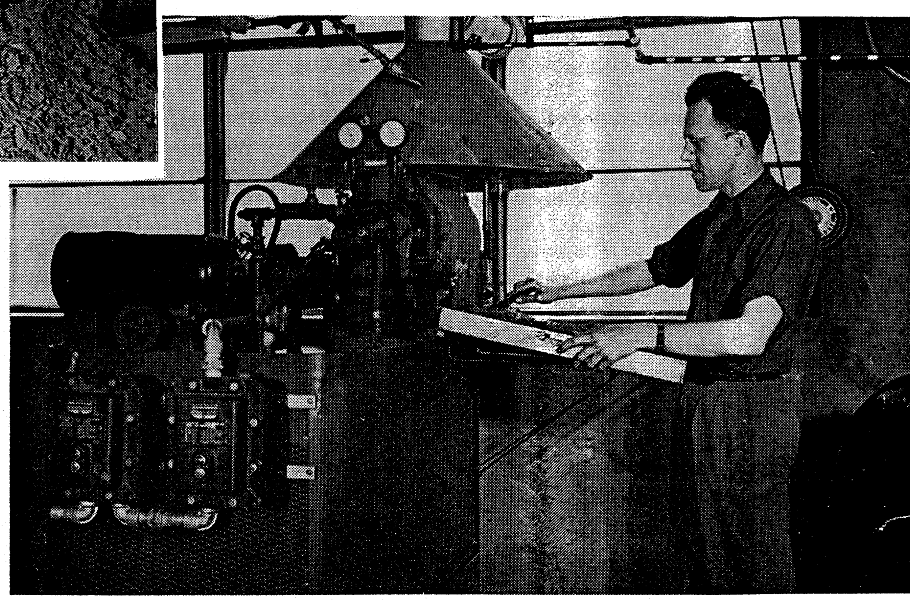
The first commercially feasible procedure for the preparation of a purified grade of oleic acid (purity, 85 to 98 per cent) was described in 1944 by research workers at the Eastern Regional Research Laboratory. Inedible tallow or grease is the starting material. Most of the undesirable polyunsaturated acids are first eliminated by selective hydrogenation, and after hydrolysis of the selectively hydrogenated fat, a fatty acid mixture consisting mainly of solid saturated, and liquid monounsaturated acids is obtained. By solvent crystallization of the mixed acids at temperatures about 5° below zero F., a temperature well within the operating range of present day commercial practice, the solid acids precipitate and are separated by filtration. These solid acids, which correspond approximately to double-pressed stearic acid, are obtained in high yield. Recovery of the solvent from the filtrate yields a residue consisting of 85 to 90 per cent oleic acid, 1 to 3 per cent polyunsaturated acids, and the remainder saturated acids. By vacuum fractional distillation, the oleic acid content can be increased to 98 per cent.

Pilot plant and cost evaluation studies indicated that the purified oleic acid should cost only slightly more than impure "red oil." Since 1949, this improved process has been in large scale commercial operation, and the product is now available in tank car lots from several producers. Demand for this product is reported to be increasing steadily. It can be used advantageously in such fields as textile finishing and cosmetic manufacture where good color- and odor-stability and high resistance to oxidation and polymerization are required, and as a chemical intermediate. Ordinary commercial oleic acid or red oil is not a good chemical intermediate because the impurities, notably polyunsaturated acids, cause reactions to proceed inefficiently and result in low yields of desired product. For this reason, efforts to develop new uses for it have been disappointing. Purified oleic acid is a much better intermediate, from both the chemical and the dollar and cents standpoint.

The unusual promise of purified oleic acid as a chemical intermediate is due to the fact that it contains two reactive functional groups, the ethylenic group and the carboxyl group. Reaction of the ethylenic group of oleic acid yields numerous products of actual and potential value, such as mono- and dihydroxystearic acids, epoxystearic acids, arylstearic acids, and mono- and dibasic acids by cleavage with oxygen or other oxidizing agents. The hydroxy- and epoxy-acids are potentially useful in the



DRUM FILTER. *Left.* **Close-up shows filtration of crystallized fats.** *Below.* **Pilot plant purifies crystallized fat on a continuous vacuum drum filter.**



preparation of waxes, plasticizers, wetting agents, and greases. Reaction of the carboxyl group of oleic acid yields a wide variety of amides, salts (soaps), and esters. Amides of oleic acid can be readily converted to products with useful wetting, detergent, and waterproofing properties merely by the proper choice of reactions. Water-insoluble soaps of oleic acid are useful as oxidation catalysts and in the preparation of greases. The synthetic ester, glyceryl trioleate, prepared from purified oleic acid and glycerol, shows promise as an inedible olive oil substitute. Other esters of oleic acid and its ethylenic derivatives are used commercially as textile processing aids and as plasticizers.

Substantial percentages of plasticizers are used in nearly all commercial plastic products to make them pliable and resilient and to eliminate brittleness. Unfortunately, the ordinary alkyl esters of fatty acids do not have quite the properties which make them entirely acceptable as plasticizers in those plastics of the vinyl and cellulosic types which have found widest commercial acceptance. Therefore several different approaches to the problem of increased utilization of fats in plasticizers are being explored. These include modification of the fatty acid before esterification, as mentioned previously, and preparation of esters having complex alcohol groups. Still another type of plasticizer or plastic modifier may be prepared by condensation of hydroxy acids, with themselves or with modifying materials.

A still different approach to the use of fat derivatives in plastics is now being investigated at the Eastern Regional Laboratory. Vinyl esters and ethers of long-chain acids and alcohols are being studied for use with other ingredients in the preparation of the familiar vinyl type plastics used in shower curtains, plastic sheets, seat covers, and similar products. Preparation of products in this manner, by which the fatty material that contributes pliability and resilience becomes an integral part of the polymer, offers great hope for minimizing the numerous generic defects which arise in use from plasticizer migration and loss. Everyone is familiar with some of these defects such as cracking, loss of pliability and clouding, which have constituted a serious disadvantage to plastics in many uses. Integrally plasticized polymers also offer some hope that if further softening is required the cheaper and readily available fatty derivatives might be more successfully used.

It seems probable that the greatest use of fats and fat derivatives in plastics would follow closely on the heels of development of a completely satisfactory process for preparing dibasic acids, such as azelaic acid, from fats. Most processes now in use or proposed require expensive and corrosive oxidizing agents, but a really satisfactory and economical process for preparing dibasic acids could easily result in utilization of millions of pounds of fats per year. Dibasic acids such as azelaic acid are not only valuable in the preparation of alkyds, polyester resins, and plasticizers but also serve as a basis for synthesizing excellent grease and lubricating oil bases. These oils and greases show little change in viscosity with change in temperature, and therefore they are particularly valuable for use in aircraft and other military machinery which are exposed to wide variations in temperature and frequently must be used under severely adverse conditions.

The field of additives to lubricants is also an actively growing one in which fats and their derivatives offer considerable promise. Lubricants being marketed frequently contain 5 to 10 per cent or even more material which has been added to improve performance in a variety of ways, such as accentuation of "oiliness," increase in viscosity index, lowering of "pour point," inhibition of oxidation, and inhibition of corrosion. Frequently an additive serves more than one purpose, and this gives such a product competitive advantage. Derivatives and products from animal fats have long been used in the preparation of greases and special lubricating products. Increasing requirements being placed on such lubricants by both military and civilian users encourage the development and production of improved fat products for this use. The hydroxy acids mentioned above offer special promise in this field.

An important use for fat derivatives being developed by a major processor of fat lies in the enrichment of certain low-grade ores by flotation processes. As our decreasing mineral resources require us to turn to lower grades of ore, this use may be expected to expand considerably.

It is not desirable to give attention exclusively to the isolation of fatty acids and other derived products from fats, because new uses may also stem from the glycerides. Years ago tallow was tried for certain metallurgical applications, such as hot dip tinning, but was rejected in favor of palm oil. Research has now yielded information necessary for the preparation of a product from animal fats which shows distinct advantages for this use. This development not only promises to constitute an important outlet for animal fats, but also relieves us from dependence upon importation of a strategic material.

It is obvious that utilization of animal fats and oils is in a continued state of flux. In some fields they are meeting increased competition from non-fat products; in others their use is decreasing. It seems certain that increased knowledge regarding their chemical and physical properties is essential to increased utilization, which in the long run can result only from making improved products and materials available to those who can use them.

TABLE I. INDUSTRIAL USES OF INEDIBLE ANIMAL FATS

- Inedible Animal Fats
  - Cutting Oils
  - Detergents
  - Electrical Insulation
  - Fatty Acids
    - Palmitic
    - Stearic
    - Oleic
      - Candles
      - Carbon Paper
      - Chemicals
      - Coatings
      - Cosmetics
      - Detergents
      - Drugs
      - Emulsifiers
      - Fire Bombs
      - Fluxes
      - Fungicides
      - Greases
      - Heavy Metal Salts
      - Insecticides
      - Lubricants
      - Mold Release Agents
      - Ointments
      - Ore Flotation Agents
      - Paints
      - Plastics
      - Plasticizers
      - Rubber Compounding
      - Shaving Cream
      - Soap
      - Textile Finishes
      - Varnishes
      - Waterproofing Agents
      - Waxes
  - Fuel
  - Glycerol
    - Explosives
    - Foods
    - Humectants
    - Plastics
  - Greases
  - Leather
  - Illuminants
  - Lubricants
  - Paints
  - Plasticizers
  - Printing Inks
  - Protective Coatings
  - Roofing
  - Rubber
  - Soap
  - Textile Processing
  - Varnishes
  - Waterproofing